Consolidated Water Use Efficiency 2002
Proposal Part One:
A. Project Information Form

1. Applying for (select one):
   - ☐ (a) Prop13 Urban Water Conservation Capital Outlay Grant
   - ☐ (a) Prop13 Agricultural Water Conservation Capital Outlay Feasibility Study Grant
   - ■ (a) DWR Water Use Efficiency Project

2. Principal applicant (organization or affiliation): USDA ARS Water Management Research Lab

3. Project title: Subsurface Drip Irrigation of Peach

4. Person authorized to sign and submit proposal:

Name, title	David Bryla, Plant Physiologist
Mailing address	9611 S. Riverbend Ave.
	Parlier, CA 93648
Telephone	559-596-2870
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Email	dbryla@fresno.ars.usda.gov

5. Contact person (if different)

Name, title	
Mailing address	
Telephone	
Fax	
Email	

6. Funds requested (dollar amount): $176,857 (3 years)

7. Applicant funds pledged (dollar amount): $196,192 (3 years)

8. Total project costs (dollar amount): $373,049 (3 years)

9. Estimated total quantifiable project benefits: NA

   Percentage of benefit to be accrued by applicant: NA

   Percentage of benefit to be accrued by CALFED or others: NA

Consolidated Water Use Efficiency 2002
Proposal Part One:
A. Project Information Form (continued)

10. Estimated annual amount of water to be saved (acre-feet): NA

    Estimated total amount of water to be saved (acre-feet): NA

    Over .... years

    Estimated benefits to be realized in terms of water quality, instream flow, other: NA

11. Duration of project (month/year to month/year): 10/02 – 3/05
12. State Assembly District where the project is to be conducted: 31st
13. State Senate District where the project is to be conducted: 16th
14. Congressional District(s) where the project is to be conducted: 20th
15. County where the project is to be conducted: Fresno
16. Date most recent Urban Management Plan submitted to the Department of Water Resources: NA

17. Type of applicant (select one):

- ☐ (a) city
- ☐ (b) county
- ☐ (c) city and county
- ☐ (d) joint power authority
- ☐ (e) other political subdivision of the State, including public water district
- ☐ (f) incorporated mutual water company
- ☐ (g) investor-owned utility
- ☐ (h) non-profit organization
- ☐ (i) tribe
- ☐ (j) university
- ☐ (k) state agency
- ■ (l) federal agency

18. Project focus:

- ■ (a) agriculture
- ☐ (b) urban

Consolidated Water Use Efficiency 2002
Proposal Part One:
A. Project Information Form (continued)

19. Project type (select one):
Prop 13 Urban Grant or Prop 13 Agricultural Feasibility Study Grant capital outlay project related to:

- ☐ (a) implementation of Urban Best Management Practices
- ☐ (b) implementation of Agricultural Efficient Water Management Practices
- ☐ (c) implementation of Quantifiable Objectives (include QO number(s))

....

- ☐ (d) other (specify)

....

DWR WUE Project related to:

- ☐ (e) implementation of Urban Best Management Practices
- ☐ (f) implementation of Agricultural Efficient Water Management Practices
- ☐ (g) implementation of Quantifiable Objectives (include QO number(s))
- ☐ (h) innovative projects (initial investigation of new technologies, methodologies, approaches, or institutional frameworks)
- ■ (i) research or pilot projects
- ☐ (j) education or public information programs
- ☐ (k) other (specify)

....

20. Do the actions in this proposal involve physical changes in land use, or potential future changes of land use?

- ☐ (a) yes
- ■ (b) no

If yes, the applicant must complete the CALFED PSP Land Use Checklist found at http://calfed.water.ca.gov/environment_doc.html and submit it with the proposal.

Consolidated Water Use Efficiency 2002
Proposal Part One:
B. Signature Page

By signing below, the official declares the following:

The truthfulness of all representations in the proposal;

The individual signing the form is authorized to submit the proposal on behalf of the applicant; and

The individual signing the form read and understood the conflict of interest and confidentiality section and waives any and all rights of privacy and confidentiality of the proposal on behalf of the applicant.

....	David Bryla, Plant Physiologist	2-27-02
Signature	Name and Title	Date

Consolidated Water Use Efficiency 2002
Proposal Part Two:

Project Summary

In an effort to use agricultural water efficiently throughout the state, it is important to continually develop and evaluate new irrigation techniques that have potential for reducing crop water use while still maintaining economically high yields. This strategy is a major endeavor of the USDA ARS Water Management Research Laboratory. One crop that we are very interested in investigating irrigation management practices for is peach. Peaches and nectarines are economically vital to the California agriculture industry, which produced 1.2 million tons of peaches and nectarines last year valued at $358 million. Peach trees require a considerable amount of water to produce these high yields. It is roughly estimated that California peach growers use nearly 93 billion gallons of water (equal to water use of 1.17 million people) for irrigation each year. Because of this high demand for water, even a small reduction in peach water requirements could produce considerable savings to the states water budget. In 1999, we established a long-term study site at the USDA ARS research farm in Parlier, CA to evaluate various irrigation management practices for improving water use efficiency in peach. Early results from our study indicate that young trees irrigated with subsurface drip produced significantly larger trees for a given amount of applied water than trees irrigated using more traditional methods. In fact, we estimate that trees irrigated with subsurface drip required less than half the amount of water than trees irrigated with more conventional methods. The main objective of the proposed project is to continue our studies on irrigation management practices in mature peach trees in order to identify those practices that improve water use efficiency and enhance crop productivity and fruit quality. In order to meet our objective, we will measure water use, yield and fruit quality for three years on trees irrigated at various levels and frequencies with different irrigation systems, including furrow, micro-sprinkler, surface drip, and subsurface drip. Results of this research will provide information directly useable by growers on the best methods of irrigating peach crops. Benefits to water savings could be considerable. For example, if subsurface drip irrigation reduced crop water requirements of mature trees by 10% over conventional methods and only 10% of the peach and nectarine growers converted their systems to subsurface drip, we estimate that 2,850 acre ft of water could be conserved each year. Total cost of the project is estimated at $373,049 over 2.5 years with $176,857 requested from the DWR WUE Program and $196,192 in cost sharing from USDA ARS and the California State University Agriculture Research Initiative.

A. Scope of Work: Relevance and Importance

1. Nature, Scope and Objectives.

California farmers require large quantities of water to irrigate their perennial tree and vine crops. In an effort to use agricultural water efficiently throughout the state, it is important to continually develop and evaluate new irrigation techniques that have potential for reducing crop water use while still maintaining economically high yields. This strategy is a major endeavor of the USDA ARS Water Management Research Laboratory located in Parlier, CA. Our primary goal is to determine the best irrigation management practices for increasing the profitability of growing fruits and vegetables in California while reducing on-farm water use.

One crop that we are very interested in investigating irrigation management practices for is peach. Peaches and nectarines are economically vital to the California agriculture industry, which harvests more than 100,000 acres of orchards each year (CDFA 2000). According to annual reports by the California Tree Fruit Agreement and the California Canning Peach Association, California farmers produced 1.2 million tons of peaches and nectarines last year valued at $358 million. Peach trees require a considerable amount of water to produce these high yields. It is roughly estimated that California peach growers use nearly 93 billion gallons of water (equal to water use of 1.17 million people) for irrigation each year (State of California 1998). Because of this high demand for water, even a small reduction in peach water requirements could produce considerable savings to the states water budget.

In 1999, we established a long-term study site to evaluate various irrigation management practices for improving water use efficiency in peach. At the site, approximately 2,000 trees are irrigated each growing season using different irrigation systems including furrow, micro-sprinkler, surface drip, and subsurface drip. Water is applied with each system at various levels and frequencies. In California, furrow or flood systems are typically used for irrigation in older orchards, while sprinkler and micro-sprinkler systems are often installed in newer orchards. Drip systems are not commonly used in peach orchards. Interestingly, early results from our study indicate that young trees irrigated with subsurface drip produced significantly larger trees for a given amount of applied water than trees irrigated using more traditional methods. In fact, we estimate that trees irrigated with subsurface drip required less than half the amount of water than trees irrigated with micro-sprinklers to produce similar size trees; furrow and surface drip irrigated trees were intermediate. Trunk cross-sectional area and total pruning weight (indicators of tree size) after three years of growth are summarized below in Table 1.

The main objective of the proposed project is to continue our studies on irrigation management practices in mature peach trees in order to identify those practices that 1) improve water use efficiency and 2) enhance crop productivity and fruit quality. Results of this research will provide information directly useable by growers on the best methods of irrigating peach crops.

Table 1. Trunk cross-sectional area (TCA) and cumulative pruning weight of 3-year-old peach trees irrigated with different systems and various frequencies and levels.

Irrigation system	Irrigation frequency	Number of irrig. lines[1]	Irrigation level[2]	TCA (cm^2)	Pruning weight (kg $tree^{-1}$)
Furrow	Every 7 d	-	100% ET_c	53.3	14.84
Furrow	Every 14 d	-	100% ET_c	55.0	15.33
Furrow	Every 21 d	-	100% ET_c	48.4	13.03
Furrow	Every 14 d	-	70% ET_c	52.8	15.02
Furrow	Every 14 d	-	150% ET_c	63.7	17.00
Micro-sprinkler	Daily	-	100% ET_c	33.3	8.39
Micro-sprinkler	M,W,F	-	100% ET_c	38.6	10.24
Micro-sprinkler	Every 7 d	-	100% ET_c	41.9	11.43
Micro-sprinkler	Every 14 d	-	100% ET_c	44.7	11.32
Micro-sprinkler	M,W,F	-	70% ET_c	38.9	10.03
Micro-sprinkler	M,W,F	-	150% ET_c	49.8	14.19
Surface drip	Daily	1	100% ET_c	55.4	16.77
Subsurface drip	Daily	1	100% ET_c	51.1	12.79
Subsurface drip	Daily	2	100% ET_c	61.8	18.65
Subsurface drip	Daily	3	100% ET_c	56.0	15.88
Subsurface drip	Daily	2	70% ET_c	56.4	15.55
Subsurface drip	Daily	2	150% ET_c	65.0	20.67

[1]Subsurface drip irrigation lines were placed on each side of the tree row at 8 ft. (1 line per row), 4 ft. (2 lines per row), or 4 & 8 ft. (3 lines per row); lines were buried 18 inches deep.
[2]ET_c represents crop evapotranspiration and was determined from lysimeter readings.

2. Statement of Critical Regional and State Water Issues.

The proposed project is consistent with efforts outlined in the agriculture water conservation options listed in *The California Water Plan Update* Bulletin 160-98. By incorporating irrigation systems and management practices with high water use efficiency identified by this study, California peach and nectarine growers can potentially reduce the amount of irrigation water applied to their orchards without sacrificing yield. This should result in either reduction in on-farm water use or increased fruit production on less acreage. Data gathered from this study will also provide information to growers on the optimum water requirements for peach production, reducing the potential for over-irrigation and the risk of groundwater contamination.

B. Scope of Work: Technical/Scientific Merit, Feasibility, Monitoring and Assessment

1. Experimental Design, Methods, and Facilities.

Experimental Design

The proposed research will be conducted at the USDA research farm in Parlier, CA, where in spring 1999, 2,000 freestone peach trees (*Prunus persica* (L.) Batsch cv.

Crimson Lady on ‘Nemaguard’ rootstock) were planted in a 1.6 ha field. To evaluate various systems commonly used to water peach trees, four different irrigation systems – furrow, micro-sprinkler, surface drip, and subsurface drip – were installed in the field prior to planting. Using these systems, we tested over the first 3 years after planting various irrigation strategies that can be used during early stages of tree development. Our plan for the proposed study is to continue monitoring these trees during fruit-bearing years. Measurements will be made periodically during the growing season to determine the effects of these different irrigation systems and strategies on water usage by mature peach trees, as well as the effects they have on fruit production and quality.

Thirteen different irrigation treatments are planned beginning in the 2002 growing season (Table 2). Treatments are arranged in a randomized complete block design. There are six replicate blocks per treatment and each block consists of eight trees in a row with one border tree on either end and a border row on either side; trees are spaced 1.8 m apart within rows and 4.6 m apart between rows. Irrigation is controlled automatically for each treatment by a datalogger unit (Campbell 21X) that opens and closes individual solenoid valves to regulate water flow. The datalogger adjusts irrigation amounts based on crop evapotranspiration (ET_c) values transmitted from a nearby field lysimeter containing peach trees of the same variety, spacing and age. Flowmeters will be used to periodically monitor the total amount of water applied to each treatment, and to ensure that the irrigation-control system is functioning properly. Using a fertilizer injector, nitrogen fertilizer solution (UN32) will be added continuously to the irrigation water throughout most of the growing season. Trees irrigated with micro-sprinklers (230^o spread) will be watered at daily, 7-day, or 14-day intervals, while trees irrigated with surface and subsurface drip irrigation are limited to only daily watering due to low application rates of these systems. However, in the subsurface drip treatments,

Table 2. Proposed irrigation treatments for mature peach trees.

Irrigation system	Irrigation frequency	Number of irrigation lines[1]	Irrigation level[2]
Furrow	Every 7 d	-	100% ET_c
Furrow	Every 14 d	-	100% ET_c
Micro-sprinkler	Daily	-	100% ET_c
Micro-sprinkler	Every 7 d	-	100% ET_c
Micro-sprinkler	Every 14 d	-	100% ET_c
Micro-sprinkler	Every 7 d	-	70% ET_c
Micro-sprinkler	Every 7 d	-	150% ET_c
Surface drip	Daily	1	100% ET_c
Subsurface drip	Daily	1	100% ET_c
Subsurface drip	Daily	2	100% ET_c
Subsurface drip	Daily	3	100% ET_c
Subsurface drip	Daily	2	70% ET_c
Subsurface drip	Daily	2	150% ET_c

[1]SDI lines were placed on each side of the tree row at 4 ft. (1 line), 4 & 8 ft. (2 lines), or 4, 8 & 12 ft. (3 lines).
[2]Crop evapotranspiration, ET_c, is determined from lysimeter readings.

the number and placement of irrigation lines are varied, which influences the distribution of irrigation water in the soil. The micro-irrigation systems will be compared with furrow-irrigated trees watered every 7 or 14 days. We are also evaluating in both the micro-sprinkler and the subsurface drip systems, the effects of replacing only 70% of the soil water lost due to ET_c, or replacing 150% ET_c. These higher and lower rates will help us determine if treatments are being over- or under-irrigated. Trees in each treatment are trained to a Kearney perpendicular-V (DeJong *et al.* 1995), and normal cultural practices will be followed throughout each growing season.

Methods

WATER USE EFFICIENCY: The water requirements of trees growing in each treatment will be calculated weekly using a water balance approach (Allen *et al.* 1998). The weekly water balance, expressed in terms of depletion at the end of the week is:

$$D_{r,i} = D_{r,i-1} - P_i - I_i - RO_i - CR_i + ET_{c,i} + DP_i$$

where $D_{r,i}$ root zone depletion at the end of week i [mm],
$D_{r,i-1}$ initial depletion in the root zone at the end of the previous week, i-1 [mm],
P_i precipitation during week i [mm],
I_i net irrigation depth during week i that infiltrates the soil [mm],
RO_i runoff from the soil surface during week i [mm],
CR_i capillary rise from the groundwater table during week i [mm],
$ET_{c,i}$ crop evapotranspiration during week i [mm],
DP_i water loss out of the root zone by deep percolation during week i [mm].

The initial depletion, $D_{r,i-1}$, each week will be calculated from changes in soil water content measured using time-domain reflectometry probes for shallow depths (<0.3 m) and a neutron probe and access tubes permanently installed at several representative locations in each treatment plot for deeper depths (0.3-3.0 m). The root zone will be defined by collecting soil cores every 2 months at various locations near one randomly selected tree from each treatment plot; soil cores (5-cm diam.) will be sampled to 3 m deep, divided into 20-cm increments, rinsed for roots, dried and weighed. A rain gauge will be installed in the field to measure precipitation, P_i, and the amount of irrigation water applied, I_i, will be recorded weekly using flow meters installed in each irrigation manifold. We will assume runoff, RO_i, and capillary rise, CR_i, is negligible because the fields are level and water tables are well below the bottom of the root zone. Crop evapotranspiration, ET_c, will be calculated by multiplying the crop coefficient for peach, K_c, by reference evapotranspiration, ET_o, downloaded from nearby CIMIS weather stations; calculated ET_c values will checked with actual values measured on a nearby peach lysimeter (see above). Deep percolation, DP_i, will be estimated following heavy rain or irrigation as:

$$DP_i = P_i + I_i - ET_{c,i} - D_{r,i-1}$$

Water use efficiency will be calculated as the amount of fruit harvested (see below) divided by the total amount of water required for the season.

CROP WATER AND NUTRIENT STATUS: Tree water and nutrient status will be monitored each season to determine how well each irrigation treatment is meeting the water and nutrient demands of the crop. Stomatal conductance and stem water potential will be used as indicators of tree water status and will be measured bi-weekly in each treatment using a steady-state porometer (LI-COR Model LI-1600) and a pressure chamber (Soil Moisture Equipment Model 3005), respectively, following the recommendations of Hsiao (1990). These measurements will be made at midday (1:30-3:30 PM PST). Leaf samples will be collected in June and July from each plot and analyzed for major macronutrients (N, P, K, Ca, Mg, and S) and micronutrients (B, Cu, Fe, Mn, Mo, and Zn). Nitrogen will be determined using an elemental analyzer; all other nutrients will be determined using an inductively coupled plasma emission spectrophotometer (Munter and Grande 1981).

YIELD AND FRUIT QUALITY: The peach variety used in this study is a spring-harvest variety that ripens in late-May to early-June. Fruit will be harvested based on background color charts in two or three sequential harvests each year. Fruit will be automatically counted and sized for each irrigation treatment using an automated sorter, and then weighed to determine total harvestable yield. The automated sorter is also equipped with a color sensor for quantifying skin color (chroma, huge, and luminosity) of the fruit. A subsample of fruit (100 per plot) will be measured for fruit quality characteristics. Quality will be measured as fruit firmness using a penetrometer, fresh juice pH using a pH meter, percent acidity using acid titration, soluble solids content expressed as degrees Brix using a refractometer, Brix:acid ratio, and organic acid content using an ion chromatograph (Dionex Model DX 500) following procedures used by Lo Voi *et al.* (1995).

STATISTICAL ANALYSES: Data will be analyzed using single-factor analysis of variance with irrigation treatments as a fixed factor. To compare irrigation systems, orthogonal contrasts will be performed according to procedures in Gomez & Gomez (1984). Crop water depletion, $D_{r,\,i}$, measured through time will be analyzed using repeated measures ANOVAs, with tests for irrigation treatments, time, and irrigation*time interactions (Moser *et al.*1990). If irrigation*time interactions are significant, separate ANOVAs will be done for each time period to test for irrigation effects.

Facilities and Resources

The USDA ARS Water Management Research Laboratory is located at a 120-acre research farm in Parlier, CA adjacent to the University of California Kearney Agricultural Center. The facility is well equipped with machinery for standard farm operations, and is staffed with a full-time farm crew. The main facility has approximately 1,500 sq. ft. of laboratory space available for general use, and 540 sq. ft. of laboratory space assigned to Dr. Bryla. Electronic and general workshops are also available for general use. Equipment in the laboratories available for this project include neutron probes, root elutriators and root scanning equipment, data loggers, pressure chambers, a porometer, an elemental analyzer, an ICP emission spectrometer, ion chromotographs, fume hoods, pH meters, penetrometers, refractometers, microgram and gram balances, postharvest climate-controlled chambers, refrigerator/freezers, drying ovens, plant/soil grinders, and Pentium III and IV PC's. An automated fruit sorter is available for use in the project from the Kearney Agricultural Center.

2. Task List and Schedule.

Task	Start Date	Finish date	Deliverable item	Projected cost	
				Cost[a]	Quarter[b]
Project year 1 (funding will be provided by USDA ARS and CSUF prior to 10/02)					
Determine crop water use	3/02	9/02	Identify BMP[c] for high WUE	$ 0	-
Determine crop water/nutrient status	3/02	9/02	-	0	-
Determine yield and fruit quality	5/02	7/02	Identify BMP for high yields and good fruit quality	0	-
Analyze data	10/02	2/03	-	36,870	1,2
Present results	12/02	-	Provide information to public	-	1
Project year 2					
Determine crop water use	3/03	9/03	Identify BMP[b] for high WUE	41,814	2,3,4
Determine crop water/nutrient status	3/03	9/03	-	20,906	2,3,4
Determine yield and fruit quality	5/03	7/03	Identify BMP for high yields and good fruit quality	41,814	2,3
Analyze data	10/03	2/04	-	39,620	5,6
Present results	12/03	-	Provide information to public	-	5
Project year 3					
Determine crop water use	3/04	9/04	Identify BMP[b] for high WUE	44,795	6,7,8
Determine crop water/nutrient status	3/04	9/04	-	22,397	6,7,8
Determine yield and fruit quality	5/04	7/04	Identify BMP for high yields and good fruit quality	44,795	6,7
Analyze data	10/04	2/05	-	42,348	9,10
Present & publish results	12/04	3/05	Provide information to public	37,690	9,10

[a]Cost to DWR WUE Program; see budget for cost sharing.
[b]Quarters 1-4 = FY 2003; quarters 5-8 = FY 2004; quarters 9-10 = FY 2005; tasks are separable by FY.
[c]Best management practices.

3. Monitoring and Assessment.

The following project-specific performance measures will be used to assess project success in relation to its objective:

- At annual grower meetings held at the Kearney Agricultural Center, we will conduct surveys on:
    - Interest of growers in irrigation management.
    - Current irrigation systems and practices used by growers.
    - Grower willingness to incorporate new irrigation systems and practices with high WUE.

  Concerns regarding recommended practices will be addressed at the meetings.

- Any grower changing their irrigation management practices or updating their current irrigation systems as a result of the proposed project will be interviewed to determine their successes and/or failures. Results of the interviews will be presented at future grower meetings.

4. Preliminary Plans and Specifications and Certification Statements.

Not applicable to the DWR WUE Program.

C. Qualifications of Applicants and Cooperators

1. Resumes of the Project Managers.

David Bryla, Plant Physiologist, USDA ARS Water Management Research Laboratory. *Project responsibilities*: Dr. Bryla will take the lead on the project and will be responsible for making sure that each phase of the project is carried out. His expertise is in the areas of crop water and nutrient use efficiency and requirements, irrigation and fertilization management practices, root system dynamics, crop coefficients, and production of annual and perennial crops in the San Joaquin Valley. He will supervise the postdoctoral research associate and technical and student support staff assisting with the project. Approximately 25% of his time will be dedicated to the project.

Tom Trout, Research Leader, USDA ARS, Water Management Research Laboratory. *Project responsibilities*: Dr. Trout will lend support to the project by assisting with irrigation system management and soil water measurements. His expertise is in irrigation engineering and soil water relations.

Jim Ayars, Ag Engineer, USDA ARS, Water Management Research Laboratory. *Project responsibilities*: Dr. Ayars will lend support to the project by assisting with irrigation system management and soil water measurements. His expertise is in irrigation engineering and soil water relations.

See the following attachments for project manager resumes: Bryla – Appendix 1a; Trout – Appendix 1b; Ayars – Appendix 1c

2. External Cooperators.

Scott Johnson, Pomology Extension Specialist, U.C. Kearney Agricultural Center. *Project responsibilities*: Dr. Johnson has extensive experience with stone fruit production. He will also assist in experimental planning and data analysis, as well as offer advice on any cultural practices required during the project. He has extensive experience in tree crop water relations.

See the following attachments for cooperator resume: Johnson – Appendix 1d

2. Cost Sharing.

We request $176,857 over 3 years from the DWR WUE Program. The USDA ARS Water Management Laboratory will commit $153,164 (approved) over 3 years to cover salaries and farm labor. An additional $43,028 (tentative approval) will come from the California State University Agricultural Research Initiative (CSU ARI) program. This program has already contributed $134,140 to support the research on the young trees. However, if no further funding comes from this source, USDA ARS will cover the cost share in order to complete the project.

3. Potential Benefits to be Realized and Information to be Gained.

Peach and nectarine growers require an average of 2.8 acre ft of irrigation water for their crop each year (CDFA 1996). The proposed research will identify irrigation management practices that increase yield and improve fruit quality and crop water use efficiency for peach production. This information could also be applied to other stone fruits grown in California, including nectarines, apricots and plums, and eventually to other tree and vine crops. Benefits to water savings could be considerable. For example, if subsurface drip irrigation reduced crop water requirements of mature trees by 10% over conventional methods (a conservative estimate – see above) and only 10% of the peach and nectarine growers converted their systems from micro-sprinklers to subsurface drip (a relatively inexpensive conversion), we estimate that 2,850 acre ft of water could be conserved each year. This value would grow as more and more growers converted their irrigation systems to subsurface drip. Additional benefits gained by using subsurface drip may include higher irrigation distribution uniformity, improved nutrient management (fertigation), restrained weed growth, and the ability to use implement traffic while irrigation is in progress. Coupled with proper nutrient management practices, subsurface drip irrigation may also help reduce nitrate groundwater contamination.

4. Benefits Realized and Information Gained Versus Costs.

Potential benefits include irrigation water savings, lower production costs, and reduced water contamination for California stone fruit production. Total cost of the project is $373,049 over 2.5 years with $176,857 requested from the DWR WUE Program and $196,192 in cost sharing from USDA ARS and CSU ARI.

E. Outreach, Community Involvement and Acceptance

The initial phase of the project on young trees has already resulted in numerous publications in newspapers, trade journals and scientific journals including *The Wall Street Journal* (Nov 2, 2000), *The LA Times* (Nov 2, 2000), *The Fresno Bee* (Nov 9, 2000), *Western Fruit Grower* (Apr 2001), *Good Fruit Grower* (Jul 2001), *California*

Farmer (Feb 2002), and *Irrigation Science* (in review). Presentations included the National Irrigation Symposium (Nov 2000) and the International Conference of the American Society for Horticultural Science (Jul 2001).

Outreach from the proposed research will continue to include presentations at scientific and industry meetings, peer-reviewed journal articles, articles in popular trade journals, and reports posted on the USDA ARS and DWR CIMIS web pages. The results of the proposed research are primarily intended to provide information to farmers growing peaches in California, as well as those servicing the needs of farmers in the region including:

- Irrigation Equipment Manufacturers
- Irrigation Consultants and PCAs
- Crop Commissions and other grower groups (California Tree Fruit Agreement, Cling Peach Growers Advisory Board)
- The Irrigation Association
- University of California Cooperative Extension
- Agricultural Scientists and Engineers

The research will also provide important information to those interested in reducing the environmental impacts of irrigated agriculture (*e.g.*, California Department of Water Resources, California Department of Food and Agriculture, USDA Natural Resources Conservation Service).

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State of California (1998) Urban, Agricultural, and Environmental Water Use. In The California Water Plan Update, Bulletin 160-98.

Appendix 1a.

Resume

David R. Bryla

Office Address: USDA ARS
Water Management Research Laboratory
9611 S. Riverbend Avenue
Parlier, California 93648
Phone: 559-596-2870
FAX: 559-559-2851

Education:
B.S., Biology, 1987, The Pennsylvania State University
M.S., Ecology, 1989, The Pennsylvania State University
Ph.D., Plant Biology, 1994, University of California, Davis

Work Experience:

1995-1998	Postdoctoral Research Associate Department of Horticulture The Pennsylvania State University
1998-1999	Postdoctoral Research Associate Department of Environmental & Resource Sci. University of Nevada, Reno
1999-present	USDA ARS Plant Physiologist Water Management Research Laboratory Parlier, CA

Research Interests:

Research is focused on determining the water and nutrient requirements of annual and perennial crops grown in the San Joaquin Valley, and developing irrigation management practices that will improve water and nutrient use efficiency and productivity of these crops.

Recent Publications:

1. Bryla DR, Duniway JM (1997a) Growth, phosphorus uptake, and water relations of safflower and wheat infected with an arbuscular mycorrhizal fungus. New Phytologist 136: 581-590.
2. Bryla DR, Duniway JM (1997b) Water uptake by safflower and wheat roots infected with arbuscular mycorrhizal fungi. New Phytologist 136: 591-601.
3. Bryla DR, Duniway JM (1997c) Effects of mycorrhizal infection on drought tolerance and recovery in safflower and wheat. Plant and Soil 197: 95-103.
4. Bryla DR, Bouma TJ, Eissenstat DM (1997) Root respiration in citrus acclimates to temperature and slows during drought. Plant, Cell and Environment 20: 1411-1420.

Appendix 1a (continued).

5. Bryla DR, Duniway JM (1998) The influence of the mycorrhiza Glomus etunicatum on drought acclimation in safflower and wheat. Physiologia Plantarum 104: 87-96.
6. Bryla DR, Koide RT (1998) Mycorrhizal response of two tomato genotypes relates to their ability to acquire and utilize phosphorus. Annals of Botany 82: 849-857.
7. Bouma TJ, Bryla DR (2000) On the assessment of root and soil respiration for soils of different textures: Interactions with soil moisture contents and soil CO_2 concentrations. Plant and Soil 227: 215-221.
8. Bouma TJ, Bryla D, Li Y, Eissenstat D (2000) Is maintenance respiration in roots constant? In The Supporting Roots of Trees and Woody Plants: Form, Function and Physiology (ed A Stokes), pp. 391-396. Developments in Plant and Soil Sciences, Vol. 87, Kluwer Academic Publishers, Dordrecht, NL.
9. Bryla DR, Bouma TJ, Hartmond U, Eissenstat DM (2001) Influence of temperature and soil drying on respiration of individual roots in citrus: Integrating greenhouse observations into a predictive model for the field. Plant, Cell and Environment 24:781-790.
10. Banuelos GS, Bryla DR, Cook C (2002) Vegetative production of kenaf and canola under irrigation in central California. Industrial Crops and Products (in press).
11. Bryla DR, Banuelos GS, Mitchell JP (2002) Water requirements of subsurface drip irrigated faba bean (*Vicia faba* L.) used for winter cover in the San Joaquin Valley, California. Irrigation Science (in press).
12. Basile B, Marsal J, Solari LI, Tyree MT, Bryla DR, DeJong TM (2002) Hydraulic conductance of peach trees grafted on rootstocks with differing size-controlling potentials. Plant, Cell and Environment (in press).
13. Resendes ML, Bryla DR, Eissenstat DM (2002) Fungal development in newly emerging roots of mature apple trees: Evidence for protective benefits from mycorrhizal fungi. Ecology (submitted).
14. Bryla DR, Trout TJ, Johnson RS, Ayars JE (2002) Irrigation and nitrogen management practices for maximizing growth and improving crop water and nutrient use efficiency in young peach trees. Irrigation Science (submitted).

Appendix 1b.
Resume
Thomas J. Trout

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Education:
B.S., Mechanical Eng., 1972, Case Western Reserve University
M.S., Agricultural Engineering, 1975, Colorado State University
Ph.D., Agricultural Engineering, 1979, Colorado State University

Work Experience:

1978-1982	Research Assistant Professor Department of Agricultural and Chemical Eng. Colorado State University
1982-1995	USDA ARS Agriculture Engineer Northwest Irrigation & Soils Research Laboratory Kimberly, ID
1995-present	USDA ARS Research Leader Water Management Research Laboratory Parlier, CA

Research Interests:

Principle research area is farm-level irrigation water management with emphasis on surface irrigation and microirrigation systems and soil water relationships. Present work includes finding ways to increase soil infiltration rates including the use of polyacrylamide; management practices that improve water distribution under surface and microirrigation; modeling and controlling soil erosion under surface irrigation; and determining microirrigation system configurations that efficiently and effectively deliver water to plants and are economical and practical. Much of the water management work is with high-value annual and perennial horticultural crops.

Recent Publications:

1. Van Schilfgaarde J, Trout TJ (1997) The future of irrigation. Proceedings of 27th Congress of the International Association for Hydraulic Research ASCE, August 10-15, 1997. Pp. 250-255.

Appendix 1b (continued).

2. Sojka RE, Lentz RD, Ross CW, Trout TJ, Bjorneberg DL, Aase JK (1998) Polyacrylamide effects on infiltration in irrigated agriculture. J. Soil and Water Cons. 53:325-331.
3. Pereira LS, Trout TJ (1999) Irrigation methods. CIGR handbook of Ag Eng, Vol I. Pp. 297-379.
4. Bjorneberg DL, Trout TJ, Sojka RE, Aase JK (2000) Evaluating WEPP-predicted Infiltration, Runoff, and Soil Erosion for Furrow Irrigation. Transactions of the ASAE, Vol. 42:1733-1741.
5. Bjorneberg DL, Kincaid DC, Lentz RD, Sojka RE, Trout TJ (2000) Unique aspects of modeling irrigation-induced soil erosion. International Journal of Sediment Research, 15:245-252.
6. Johnson RS, Ayars J, Trout T, Mead R, Phene C (2000) Crop coefficients for mature peach trees are well correlated with midday canopy light interception. Proc. 3rd International Symposium on Irrigation Horticultural Crops. Acta. Hort. 537:455-460.
7. Hanson BR, Trout TJ (2001) Irrigated Agriculture and Water Quality Impacts. Agricultural Nonpoint Source Pollution. Watershed Management and Hydrology. Pp. 169-206.

Appendix 1c.
Resume
James E. Ayars

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Education: B.S., Agricultural Engineering, 1965, Cornell University
M.S., Agricultural Engineering, 1973, Colorado State University
Ph.D., Agricultural Engineering, 1976, Colorado State University

Work Experience:

1976-1980	Assistant Professor Department of Agricultural Engineering University of Maryland
1980-present	USDA ARS Agriculture Engineer Water Management Research Laboratory Parlier, CA

Research Activities:

Research activities include (1) field studies of irrigation and drainage management to reduce drain flow; (2) use of saline drainage water for supplemental irrigation; (3) water management studies of irrigation districts; (4) studies on the effect of irrigation management on drainage water quality; (5) integrated management of irrigation and drainage systems in arid areas; (6) water requirements perennial crops; (7) drainage design incorporating water quality criteria.

Recent Publications:

1. Guitjens JC, Ayars JE, Grismer ME, Willardson LS (1997) Drainage design for Water Quality Management: Overview. Journal of Irrigation and Drainage Engineering 123:148-154.
2. Ayars JE, Grismer ME, Guitjens JC (1997) Water quality as a design criterion in drainage water management systems. Journal of Irrigation and Drainage Engineering 123:154-158.
3. Ayars JE, Soppe RW, Cone D, Wichlens D (1997) Managing salt load in irrigation district drainage water. Proceedings of 27th Congress for Hydraulic Research ASCE, August 10-15, pp. 250-113

Appendix 1c (continued).

4. Itenfisu D, Allen RG, Phene CJ, Ayars JE, Hutmacher RB (1997) Integrity of Lysimeter Measurements for Evapotranspiration. Proc. Tech. Program of the Irrigation Association Annual Meeting. Nashville, Tenn., 8 p.
5. Ayars JE, Schoneman RA, Soppe RW, Mead RM (1998) Irrigating cotton in the presence of shallow groundwater. Proc. 7th Ann. Drain. Symp., Orlando, FL, pp. 82-89.
6. Ayars JE, Wichlens D, Cone D (1998) Water management principles for drainage reduction and a case study of the Broadview Water District. Proceedings, AAAS Symposium, Toxic Trace Elements and Sustainability in Agroecosystems, San Francisco, CA. 19-23 June, ed L.M. Dudley, J.C. Guitjens, pg. 159-182.
7. Ayars JE, Schoneman RA, Soppe RW (1998) Strategies for utilizing shallow groundwater in arid areas. Proceedings from the USCID 14th Technical Conference on Irrigation, Drainage and Flood Control, Phoenix, AZ, pp. 81-96.
8. Ayars JE (1999) Integrated management of irrigation and drainage systems. In: Water Management, Purification and Conservation in Arid Climates, pp. 139-164.
9. Ayars JE, Phene CJ, Hutmacher RB, Davis KR, Schoneman RA, Vail SS, Mead RM (1999) Subsurface drip irrigation of row crops: a review of 15 years of research at the Water Management Research Laboratory. Agricultural Water Management 42:1-27.
10. Ayars JE, Tanji KK (1999) Effects of Drainage on water quality in arid and semiarid irrigated lands. In: ASA Monograph on Drainage, #38.
11. Schoneman R, Ayars JE (1999) Continuous measurement of drainage discharge. Applied Engineering in Agriculture 15:435-439.
12. Ayars JE, Hutmacher RB, Schoneman RA, Soppe RW, Vail SS, Dale F (2000) Realizing the potential of integrated irrigation and drainage water management for meeting crop water requirements in semi-arid and arid areas. Irrigation and Drainage Systems 13:321-347.
13. Johnson RS, Ayars J, Trout T, Mead R, Phene C (2000) Crop coefficients for mature peach trees are well correlated with midday canopy light interception. Proc. 3rd International Symposium on Irrigation Horticultural Crops. Acta. Hort. 537:455-460.

Appendix 1d.
Resume
R. Scott Johnson

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Education: B.S., Biology, 1977, University of Utah
Ph.D., Pomology, 1982, Cornell University

Work Experience:

1982-1988	Associate Extension Specialist University of California, Davis at Kearney Agricultural Center
1988-present	Extension Specialist University of California, Davis at Kearney Agricultural Center

Research Interests:

Research interests include field projects on irrigation, nutrition, thinning, rootstocks and training systems of peaches, plums, nectarines, apples and kiwifruit. The emphasis has been on developing cultural practices that improve fruit size and yield efficiency, enhance fruit quality and are environmentally sound.

Selected Publications:

1. Weinbaum SA, Johnson RS, DeJong TM (1992) Causes and consequences of over-fertilization in orchards. HortTechnology Jan/Mar 2(1):112-121.
2. Johnson RS, Handley DF, DeJong TM (1992) Long-term response of early maturing peach trees to postharvest water deficits. J. Amer. Soc. Hort. Sci. 117(6):881-886.
3. DeJong TM, Day KR, Doyle JF, Johnson RS (1994) The Kearney Agricultural Center perpendicular “V” (KAC-V) orchard system for peaches and nectarines. HortTechnology 4(4):362-367.
4. Crisosto CH, Johnson RS, Luza JG, Crisosto GH (1994) Irrigation regimes affect fruit soluble solids concentration and rate of water loss of ‘O’Henry peaches. HortScience 29(10):1169-1171.
5. Daane KM, Johnson RS, Michailides TJ, Crisosto CH, Dlott JW, Ramirez HT, Yokota GY, Morgan DP (1995) Excess nitrogen raises nectarine susceptibility to disease and insects. California Agriculture 7/8:13-18.

Appendix 1d (continued).

6. Rosecrance RC, Johnson RS, Weinbaum SA (1998) The effect of timing of post-harvest foliar urea sprays on nitrogen absorption and partitioning in peach and nectarine trees. J. Hort. Sci. & Biotech. 73(6):856-861.
7. Johnson RS, Ayars J, Trout T, Mead R, Phene C (2000) Crop coefficients for mature peach trees are well correlated with midday canopy light interception. Proc. 3rd International Symposium on Irrigation Horticultural Crops. Acta. Hort. 537:455-460.
8. Handley DF, Johnson RS (2000) Late Summer Irrigation of Water-stressed Peach Trees Reduces Fruit Doubles and Deep Sutures. HortScience 35(4):771.

D. Benefits and Costs

1. Budget Breakdown and Justification.

	DWR WUE Program			Cost-sharing			Total		
	Year 1	Year 2	Year 3	Year 1	Year 2	Year 3	Year 1	Year 2	Year 3
a. Direct Labor Hours				10,000	10,000	2,000	10,000	10,000	2,000
b. Salaries									
Bryla (25% time)				16,759	18,006	9,494	16,759	18,006	9,494
Trout									
Ayars									
Johnson									
Postdoc (100% time)	46,643	50,127	26,906				46,643	50,127	26,906
Technician (50% time)				16,023	17,548	9,346	16,023	17,548	9,346
Student assistants				9,360	10,400	5,720	9,360	10,400	5,720
c. Benefits									
Staff/Postdoc (30%)	13,993	15,038	8,072	9,835	10,666	5,652	23,828	25,704	13,724
Students (10%)				936	1,040	572	936	1,040	572
d. Travel									
e. Supplies				5,000	5,000	5,000	5,000	5,000	5,000
f. Consultant Services									
g. Equipment									
h. Other Direct Costs									
i. Total direct costs (a-h)	60,636	65,165	34,978	67,913	72,660	37,784	128,549	137,825	72,762
j. Indirect Costs	6,064	6,516	3,498	6,791	7,266	3,778	12,855	13,782	7,276
k. Total Costs (i plus j)	66,700	71,681	38,476	74,704	79,926	41,562	141,404	151,607	80,038

Justification

Direct labor hours are required for farm labor each year for pruning, thinning and harvesting. Salaries are required for the following personnel: Dr. Bryla, who will coordinate projects and disseminate results; a postdoctoral research associate, who is required for data collection and analysis; a technician, who will maintain the irrigation system and assist with data collection; and undergraduate students, who will assist with data collection. Salaries are adjusted each year for pay step and cost of living increases. Chemical and compressed are needed to run field and laboratory equipment.

July 18,2000

Block	Treament	Rep	BSD(mm)
I	F1	1	67.7
I	F1	2	51
I	F1	3	62.9
I	F1	4	64.1
I	F1	5	61.6
I	F1	6	53.3
II	F1	1	60.4
II	F1	2	56.1
II	F1	3	40.1
II	F1	4	53.2
II	F1	5	44.2
II	F1	6	46.9
III	F1	1	59.4
III	F1	2	56
III	F1	3	49.5
III	F1	4	49.9
III	F1	5	54.2
III	F1	6	48.9
IV	F1	1	44.7
IV	F1	2	47.6
IV	F1	3	44.2
IV	F1	4	48
IV	F1	5	58.4
IV	F1	6	38
V	F1	1	57.1
V	F1	2	51.9
V	F1	3	54.6
V	F1	4	57.3
V	F1	5	51.6
V	F1	6	64.4
VI	F1	1	54.1
VI	F1	2	59.4
VI	F1	3	49.9
VI	F1	4	52.1
VI	F1	5	49.9
VI	F1	6	50.6
I	F1b	1	57.5
I	F1b	2	46.4
I	F1b	3	62.3
I	F1b	4	65.3
I	F1b	5	57
I	F1b	6	64
II	F1b	1	52.1
II	F1b	2	56.7
II	F1b	3	14.4
II	F1b	4	38.1
II	F1b	5	45.8
II	F1b	6	43
III	F1b	1	58.5
III	F1b	2	55.5
III	F1b	3	45.8

III	F1b	4	45.9
III	F1b	5	45.9
III	F1b	6	42.2
IV	F1b	1	42.2
IV	F1b	2	41.9
IV	F1b	3	44.9
IV	F1b	4	51.2
IV	F1b	5	52.3
IV	F1b	6	44.2
V	F1b	1	62.9
V	F1b	2	63.5
V	F1b	3	62
V	F1b	4	55.5
V	F1b	5	62.3
V	F1b	6	66
VI	F1b	1	62.1
VI	F1b	2	49.4
VI	F1b	3	56.3
VI	F1b	4	34.2
VI	F1b	5	63.7
VI	F1b	6	53.8
I	F1c	1	53.4
I	F1c	2	65.6
I	F1c	3	58.4
I	F1c	4	56
I	F1c	5	56.9
I	F1c	6	56.1
II	F1c	1	61.3
II	F1c	2	52.1
II	F1c	3	34.9
II	F1c	4	56.5
II	F1c	5	47.6
II	F1c	6	53.6
III	F1c	1	62.5
III	F1c	2	50.4
III	F1c	3	43.1
III	F1c	4	46.3
III	F1c	5	47.5
III	F1c	6	45.5
IV	F1c	1	58.1
IV	F1c	2	38.2
IV	F1c	3	45.6
IV	F1c	4	55.4
IV	F1c	5	58.8
IV	F1c	6	54.6
V	F1c	1	60
V	F1c	2	53
V	F1c	3	61.3
V	F1c	4	56.6
V	F1c	5	61.5
V	F1c	6	59
VI	F1c	1	58.8
VI	F1c	2	61.2

VI	F1c	3	47.5
VI	F1c	4	46.7
VI	F1c	5	49.3
VI	F1c	6	54.1
I	F2	1	51
I	F2	2	37.5
I	F2	3	56.7
I	F2	4	58.5
I	F2	5	51
I	F2	6	57.2
II	F2	1	54.2
II	F2	2	57
II	F2	3	52.3
II	F2	4	55.2
II	F2	5	56.3
II	F2	6	55.5
III	F2	1	54
III	F2	2	54
III	F2	3	48.2
III	F2	4	54.8
III	F2	5	53.8
III	F2	6	61.7
IV	F2	1	55.7
IV	F2	2	50.5
IV	F2	3	55.1
IV	F2	4	48.7
IV	F2	5	59.2
IV	F2	6	46.5
V	F2	1	51.2
V	F2	2	57.7
V	F2	3	58.3
V	F2	4	55.1
V	F2	5	69.2
V	F2	6	56.6
VI	F2	1	49.1
VI	F2	2	54.7
VI	F2	3	57.8
VI	F2	4	54.8
VI	F2	5	51.8
VI	F2	6	43.8
I	F2b	1	54.1
I	F2b	2	47.9
I	F2b	3	51
I	F2b	4	54.4
I	F2b	5	55.8
I	F2b	6	59.6
II	F2b	1	70.3
II	F2b	2	58.9
II	F2b	3	52.3
II	F2b	4	45.5
II	F2b	5	60.2
II	F2b	6	45.6
III	F2b	1	64.4

III	F2b	2	56.9
III	F2b	3	45.3
III	F2b	4	50.5
III	F2b	5	48.5
III	F2b	6	55.5
IV	F2b	1	43.4
IV	F2b	2	42.2
IV	F2b	3	24.8
IV	F2b	4	54
IV	F2b	5	48.1
IV	F2b	6	42.5
V	F2b	1	51.3
V	F2b	2	42.4
V	F2b	3	53.3
V	F2b	4	65.2
V	F2b	5	71.9
V	F2b	6	51.1
VI	F2b	1	54.9
VI	F2b	2	50.7
VI	F2b	3	45.7
VI	F2b	4	52.8
VI	F2b	5	47.3
VI	F2b	6	14.7
I	F2c	1	62.2
I	F2c	2	15.8
I	F2c	3	54.2
I	F2c	4	55.5
I	F2c	5	48.7
I	F2c	6	48
II	F2c	1	54.9
II	F2c	2	62.1
II	F2c	3	51.1
II	F2c	4	48.5
II	F2c	5	52.6
II	F2c	6	50.6
III	F2c	1	69.4
III	F2c	2	56.1
III	F2c	3	47.7
III	F2c	4	55.1
III	F2c	5	65
III	F2c	6	57.9
IV	F2c	1	59
IV	F2c	2	55.1
IV	F2c	3	50.8
IV	F2c	4	59.2
IV	F2c	5	56.6
IV	F2c	6	53.5
V	F2c	1	52.1
V	F2c	2	60.6
V	F2c	3	50.9
V	F2c	4	67.6
V	F2c	5	69
V	F2c	6	55

VI	F2c	1	52.5
VI	F2c	2	64.5
VI	F2c	3	22.4
VI	F2c	4	69.3
VI	F2c	5	60.1
VI	F2c	6	63.4
I	M1	1	57.1
I	M1	2	51.3
I	M1	3	53.9
I	M1	4	48.3
I	M1	5	58
I	M1	6	55.7
II	M1	1	63.1
II	M1	2	56.8
II	M1	3	52.6
II	M1	4	44.9
II	M1	5	53.7
II	M1	6	52
III	M1	1	36.8
III	M1	2	48.5
III	M1	3	40.3
III	M1	4	40.3
III	M1	5	39.5
III	M1	6	29.6
IV	M1	1	46.9
IV	M1	2	41.7
IV	M1	3	46.4
IV	M1	4	48.2
IV	M1	5	51.9
IV	M1	6	35.7
V	M1	1	53.2
V	M1	2	51
V	M1	3	36.9
V	M1	4	42.2
V	M1	5	44
V	M1	6	57.7
VI	M1	1	55.9
VI	M1	2	53.2
VI	M1	3	53.5
VI	M1	4	53.4
VI	M1	5	54.3
VI	M1	6	50.2
I	M1b	1	58.3
I	M1b	2	50.2
I	M1b	3	64.2
I	M1b	4	47.6
I	M1b	5	64.4
I	M1b	6	57.5
II	M1b	1	54.9
II	M1b	2	55.2
II	M1b	3	43.8
II	M1b	4	55.8
II	M1b	5	52.9

II	M1b	6	43.4
III	M1b	1	37.2
III	M1b	2	48.5
III	M1b	3	31.2
III	M1b	4	32.4
III	M1b	5	29
III	M1b	6	28.8
IV	M1b	1	39.1
IV	M1b	2	50.9
IV	M1b	3	14
IV	M1b	4	45.8
IV	M1b	5	45.4
IV	M1b	6	35.1
V	M1b	1	49
V	M1b	2	56
V	M1b	3	50
V	M1b	4	44
V	M1b	5	54.4
V	M1b	6	54.5
VI	M1b	1	59.7
VI	M1b	2	53.9
VI	M1b	3	50.4
VI	M1b	4	46.5
VI	M1b	5	49.5
VI	M1b	6	49.4
I	M1c	1	59.5
I	M1c	2	56
I	M1c	3	54.8
I	M1c	4	50.8
I	M1c	5	64.9
I	M1c	6	60.6
II	M1c	1	53.4
II	M1c	2	62.1
II	M1c	3	45.2
II	M1c	4	45
II	M1c	5	29
II	M1c	6	60.2
III	M1c	1	46.6
III	M1c	2	59.5
III	M1c	3	34.7
III	M1c	4	41.6
III	M1c	5	49
III	M1c	6	42.1
IV	M1c	1	37.5
IV	M1c	2	40
IV	M1c	3	39.6
IV	M1c	4	18.5
IV	M1c	5	56.2
IV	M1c	6	34.6
V	M1c	1	49.2
V	M1c	2	49.8
V	M1c	3	38.7
V	M1c	4	58

V	M1c	5	27.7
V	M1c	6	55.5
VI	M1c	1	46.5
VI	M1c	2	53.5
VI	M1c	3	55.4
VI	M1c	4	46.4
VI	M1c	5	56.4
VI	M1c	6	53.3
I	M2	1	65.1
I	M2	2	59.2
I	M2	3	65.5
I	M2	4	60
I	M2	5	56.6
I	M2	6	49.8
II	M2	1	63.8
II	M2	2	66.8
II	M2	3	46.8
II	M2	4	48.4
II	M2	5	57
II	M2	6	58.1
III	M2	1	46.1
III	M2	2	42.6
III	M2	3	46.6
III	M2	4	42.1
III	M2	5	41.5
III	M2	6	47.1
IV	M2	1	56.5
IV	M2	2	50.3
IV	M2	3	58.9
IV	M2	4	37.9
IV	M2	5	61
IV	M2	6	55.1
V	M2	1	65.4
V	M2	2	56
V	M2	3	59.6
V	M2	4	54.4
V	M2	5	51.1
V	M2	6	51.9
VI	M2	1	56
VI	M2	2	54.8
VI	M2	3	64.5
VI	M2	4	47.9
VI	M2	5	52.6
VI	M2	6	58.2
I	M2b	1	48.5
I	M2b	2	56.5
I	M2b	3	57.7
I	M2b	4	58.5
I	M2b	5	55.7
I	M2b	6	53.2
II	M2b	1	60.4
II	M2b	2	53
II	M2b	3	35.7

II	M2b	4	47.8
II	M2b	5	55.9
II	M2b	6	53.2
III	M2b	1	45.1
III	M2b	2	40.8
III	M2b	3	38.4
III	M2b	4	39.7
III	M2b	5	43.3
III	M2b	6	41
IV	M2b	1	57.3
IV	M2b	2	52.8
IV	M2b	3	48.5
IV	M2b	4	52.6
IV	M2b	5	61.5
IV	M2b	6	47.5
V	M2b	1	59.6
V	M2b	2	60.9
V	M2b	3	38.4
V	M2b	4	58.6
V	M2b	5	52
V	M2b	6	53.2
VI	M2b	1	55.4
VI	M2b	2	61.8
VI	M2b	3	56.9
VI	M2b	4	51.7
VI	M2b	5	49.9
VI	M2b	6	53
I	M2c	1	57.1
I	M2c	2	51.2
I	M2c	3	63.8
I	M2c	4	64.2
I	M2c	5	61.5
I	M2c	6	50.5
II	M2c	1	62.7
II	M2c	2	63.3
II	M2c	3	47.7
II	M2c	4	58.2
II	M2c	5	65.5
II	M2c	6	58.5
III	M2c	1	43.2
III	M2c	2	34.1
III	M2c	3	39.5
III	M2c	4	38.9
III	M2c	5	37.2
III	M2c	6	28.9
IV	M2c	1	53.4
IV	M2c	2	50.3
IV	M2c	3	63.3
IV	M2c	4	52.2
IV	M2c	5	65
IV	M2c	6	46.5
V	M2c	1	58.6
V	M2c	2	61.3

V	M2c	3	41.3
V	M2c	4	59.8
V	M2c	5	53.9
V	M2c	6	52.5
VI	M2c	1	57
VI	M2c	2	56.3
VI	M2c	3	59.3
VI	M2c	4	52.9
VI	M2c	5	48.6
VI	M2c	6	54.3
I	M3	1	60.9
I	M3	2	50.4
I	M3	3	55.8
I	M3	4	54.2
I	M3	5	60
I	M3	6	40.2
II	M3	1	56.4
II	M3	2	53.4
II	M3	3	48.7
II	M3	4	38.9
II	M3	5	49.7
II	M3	6	40.5
III	M3	1	50.6
III	M3	2	50.1
III	M3	3	40.8
III	M3	4	40.1
III	M3	5	47.7
III	M3	6	42.3
IV	M3	1	55.1
IV	M3	2	44
IV	M3	3	60.6
IV	M3	4	58
IV	M3	5	54.9
IV	M3	6	55.4
V	M3	1	59.7
V	M3	2	54.7
V	M3	3	59.2
V	M3	4	53.8
V	M3	5	55.9
V	M3	6	55.5
VI	M3	1	56.3
VI	M3	2	55.5
VI	M3	3	50.6
VI	M3	4	60.3
VI	M3	5	54.8
VI	M3	6	65
I	M3b	1	47.5
I	M3b	2	53.6
I	M3b	3	60.9
I	M3b	4	55.5
I	M3b	5	56.7
I	M3b	6	60.4
II	M3b	1	57.1

II	M3b	2	57.2
II	M3b	3	50.1
II	M3b	4	42.5
II	M3b	5	46.1
II	M3b	6	48.9
III	M3b	1	49.8
III	M3b	2	44.3
III	M3b	3	38.4
III	M3b	4	40.3
III	M3b	5	51.3
III	M3b	6	45.3
IV	M3b	1	55.7
IV	M3b	2	50
IV	M3b	3	66.8
IV	M3b	4	60.7
IV	M3b	5	50.4
IV	M3b	6	52.4
V	M3b	1	59.4
V	M3b	2	54.5
V	M3b	3	51.1
V	M3b	4	57.1
V	M3b	5	61.1
V	M3b	6	50.9
VI	M3b	1	61.1
VI	M3b	2	53.1
VI	M3b	3	51.1
VI	M3b	4	53.4
VI	M3b	5	54.6
VI	M3b	6	62.4
I	M3c	1	15.9
I	M3c	2	50.6
I	M3c	3	55.8
I	M3c	4	54.8
I	M3c	5	61.1
I	M3c	6	54.4
II	M3c	1	60.6
II	M3c	2	52
II	M3c	3	49.3
II	M3c	4	50.6
II	M3c	5	46.6
II	M3c	6	17.6
III	M3c	1	59.2
III	M3c	2	51.6
III	M3c	3	44.7
III	M3c	4	40.6
III	M3c	5	53
III	M3c	6	45.5
IV	M3c	1	52.8
IV	M3c	2	48.8
IV	M3c	3	66
IV	M3c	4	52
IV	M3c	5	43.5
IV	M3c	6	44.3

V	M3c	1	59
V	M3c	2	57.7
V	M3c	3	58.4
V	M3c	4	51.3
V	M3c	5	64.8
V	M3c	6	57.6
VI	M3c	1	53.3
VI	M3c	2	62.4
VI	M3c	3	47.6
VI	M3c	4	58.4
VI	M3c	5	58.8
VI	M3c	6	52.5
I	M4	1	52.5
I	M4	2	52.4
I	M4	3	59
I	M4	4	51.4
I	M4	5	65.9
I	M4	6	58.9
II	M4	1	68.8
II	M4	2	66.8
II	M4	3	46.8
II	M4	4	48.4
II	M4	5	57
II	M4	6	58.1
III	M4	1	41.5
III	M4	2	50.1
III	M4	3	45.4
III	M4	4	29.9
III	M4	5	40.9
III	M4	6	34.8
IV	M4	1	52.5
IV	M4	2	50.2
IV	M4	3	38.6
IV	M4	4	41.6
IV	M4	5	41.8
IV	M4	6	57.2
V	M4	1	51.8
V	M4	2	56.8
V	M4	3	55.5
V	M4	4	41.6
V	M4	5	57.5
V	M4	6	61.8
VI	M4	1	48.1
VI	M4	2	54.1
VI	M4	3	51.1
VI	M4	4	62.2
VI	M4	5	59.5
VI	M4	6	47.1
I	M4b	1	50
I	M4b	2	52
I	M4b	3	59.6
I	M4b	4	46
I	M4b	5	61.7

I	M4b	6	55
II	M4b	1	54.7
II	M4b	2	54.8
II	M4b	3	44
II	M4b	4	60.6
II	M4b	5	62
II	M4b	6	56.2
III	M4b	1	50.2
III	M4b	2	47.8
III	M4b	3	46.3
III	M4b	4	42
III	M4b	5	46.3
III	M4b	6	43
IV	M4b	1	47.4
IV	M4b	2	44.6
IV	M4b	3	62
IV	M4b	4	55.3
IV	M4b	5	44
IV	M4b	6	39.9
V	M4b	1	58.9
V	M4b	2	11.9(Dead)
V	M4b	3	34.9
V	M4b	4	40.2
V	M4b	5	59.9
V	M4b	6	59.3
VI	M4b	1	58.8
VI	M4b	2	54.8
VI	M4b	3	55.3
VI	M4b	4	61.2
VI	M4b	5	62.4
VI	M4b	6	55.2
I	M4c	1	56.7
I	M4c	2	55.3
I	M4c	3	61.8
I	M4c	4	55.7
I	M4c	5	62.5
I	M4c	6	59.6
II	M4c	1	58.9
II	M4c	2	52.8
II	M4c	3	66.5
II	M4c	4	60.9
II	M4c	5	58.5
II	M4c	6	56.9
III	M4c	1	48.2
III	M4c	2	53
III	M4c	3	43.2
III	M4c	4	38.1
III	M4c	5	34
III	M4c	6	40.4
IV	M4c	1	38.4
IV	M4c	2	47.1
IV	M4c	3	52.3
IV	M4c	4	50.1

IV	M4c	5	40.9
IV	M4c	6	46.8
V	M4c	1	58.9
V	M4c	2	52.8
V	M4c	3	66.5
V	M4c	4	60.9
V	M4c	5	58.5
V	M4c	6	56.9
VI	M4c	1	56.4
VI	M4c	2	56.8
VI	M4c	3	56
VI	M4c	4	62.6
VI	M4c	5	56.1
VI	M4c	6	48.9
I	M5	1	61.4
I	M5	2	49.2
I	M5	3	57.5
I	M5	4	67.2
I	M5	5	53.2
I	M5	6	58.6
II	M5	1	38
II	M5	2	38.2
II	M5	3	57.6
II	M5	4	46.2
II	M5	5	48.6
II	M5	6	57.1
III	M5	1	46.2
III	M5	2	39.2
III	M5	3	41.3
III	M5	4	45.2
III	M5	5	39
III	M5	6	37.8
IV	M5	1	61.5
IV	M5	2	66.3
IV	M5	3	56
IV	M5	4	13.1
IV	M5	5	64.4
IV	M5	6	47.5
V	M5	1	60.4
V	M5	2	49.6
V	M5	3	51.3
V	M5	4	54.1
V	M5	5	58.3
V	M5	6	48.5
VI	M5	1	61
VI	M5	2	53.1
VI	M5	3	49.5
VI	M5	4	53.3
VI	M5	5	53.5
VI	M5	6	46.1
I	M5b	1	62.5
I	M5b	2	49.4
I	M5b	3	59.4

I	M5b	4	61.4
I	M5b	5	58.3
I	M5b	6	58.2
II	M5b	1	38.5
II	M5b	2	44.8
II	M5b	3	53
II	M5b	4	54
II	M5b	5	54.2
II	M5b	6	49.5
III	M5b	1	46.3
III	M5b	2	53.4
III	M5b	3	56.4
III	M5b	4	47.7
III	M5b	5	52
III	M5b	6	45.3
IV	M5b	1	57.5
IV	M5b	2	55.5
IV	M5b	3	56.1
IV	M5b	4	57.2
IV	M5b	5	54.4
IV	M5b	6	50.6
V	M5b	1	53.5
V	M5b	2	44.5
V	M5b	3	43.7
V	M5b	4	46.5
V	M5b	5	56.4
V	M5b	6	41
VI	M5b	1	59.9
VI	M5b	2	52.9
VI	M5b	3	48.7
VI	M5b	4	61.9
VI	M5b	5	56.5
VI	M5b	6	59
I	M5c	1	54.4
I	M5c	2	47.6
I	M5c	3	54.6
I	M5c	4	61.4
I	M5c	5	62.7
I	M5c	6	60
II	M5c	1	41.7
II	M5c	2	42.3
II	M5c	3	52.7
II	M5c	4	49
II	M5c	5	49.2
II	M5c	6	56.2
III	M5c	1	39.2
III	M5c	2	42.5
III	M5c	3	44.7
III	M5c	4	38.2
III	M5c	5	40.3
III	M5c	6	17
IV	M5c	1	59.5
IV	M5c	2	61.1

IV	M5c	3	61.4
IV	M5c	4	59.3
IV	M5c	5	60
IV	M5c	6	57.1
V	M5c	1	15.4
V	M5c	2	52.3
V	M5c	3	58.9
V	M5c	4	45.5
V	M5c	5	50.4
V	M5c	6	51.3
VI	M5c	1	60.5
VI	M5c	2	53.2
VI	M5c	3	59.2
VI	M5c	4	63.9
VI	M5c	5	56.4
VI	M5c	6	53.8
I	S1	1	48.4
I	S1	2	52.1
I	S1	3	59
I	S1	4	51.5
I	S1	5	49.2
I	S1	6	57.9
II	S1	1	61.6
II	S1	2	59.5
II	S1	3	35.8
II	S1	4	53.7
II	S1	5	62.4
II	S1	6	62.2
III	S1	1	53.7
III	S1	2	59.7
III	S1	3	52
III	S1	4	43.7
III	S1	5	59.4
III	S1	6	47.3
IV	S1	1	64.1
IV	S1	2	57
IV	S1	3	50.1
IV	S1	4	51.9
IV	S1	5	56.6
IV	S1	6	53.6
V	S1	1	65
V	S1	2	60.7
V	S1	3	58.6
V	S1	4	64.9
V	S1	5	53.6
V	S1	6	57.4
VI	S1	1	38.1
VI	S1	2	40.4
VI	S1	3	54.5
VI	S1	4	55.3
VI	S1	5	56.9
VI	S1	6	50.9
I	S1e	1	64.5

I	S1e	2	54.4
I	S1e	3	65.1
I	S1e	4	56.5
I	S1e	5	61.1
I	S1e	6	49.8
II	S1e	1	56.3
II	S1e	2	64.6
II	S1e	3	40.3
II	S1e	4	45.1
II	S1e	5	60.4
II	S1e	6	54.3
III	S1e	1	59.5
III	S1e	2	61.2
III	S1e	3	47.9
III	S1e	4	50.9
III	S1e	5	53.1
III	S1e	6	59.8
IV	S1e	1	47.2
IV	S1e	2	48.6
IV	S1e	3	35.7
IV	S1e	4	41.7
IV	S1e	5	57.9
IV	S1e	6	36.5
V	S1e	1	53
V	S1e	2	46.4
V	S1e	3	50.8
V	S1e	4	44.2
V	S1e	5	52.6
V	S1e	6	50.3
VI	S1e	1	67.3
VI	S1e	2	705
VI	S1e	3	66.2
VI	S1e	4	61.5
VI	S1e	5	68.6
VI	S1e	6	60.6
I	S1w	1	60.1
I	S1w	2	62.1
I	S1w	3	70.8
I	S1w	4	61.1
I	S1w	5	67
I	S1w	6	38
II	S1w	1	63.8
II	S1w	2	55.8
II	S1w	3	19.3
II	S1w	4	47
II	S1w	5	51.9
II	S1w	6	55.4
III	S1w	1	56
III	S1w	2	61.9
III	S1w	3	50
III	S1w	4	50
III	S1w	5	57.8
III	S1w	6	46.7

IV	S1w	1	56.7
IV	S1w	2	59
IV	S1w	3	45.5
IV	S1w	4	51.4
IV	S1w	5	66
IV	S1w	6	56.2
V	S1w	1	50.4
V	S1w	2	52.1
V	S1w	3	60.5
V	S1w	4	61.9
V	S1w	5	67.1
V	S1w	6	57.5
VI	S1w	1	61.3
VI	S1w	2	63
VI	S1w	3	61.5
VI	S1w	4	56.7
VI	S1w	5	77.6
VI	S1w	6	54.4
I	S3	1	62.5
I	S3	2	61.6
I	S3	3	58
I	S3	4	56.2
I	S3	5	50.5
I	S3	6	49.3
II	S3	1	57.7
II	S3	2	61.4
II	S3	3	54.4
II	S3	4	37.3
II	S3	5	62.9
II	S3	6	48.7
III	S3	1	62.6
III	S3	2	59.5
III	S3	3	58.6
III	S3	4	49
III	S3	5	57.8
III	S3	6	52.6
IV	S3	1	58.8
IV	S3	2	61.1
IV	S3	3	55.7
IV	S3	4	57.4
IV	S3	5	56
IV	S3	6	55.8
V	S3	1	55.9
V	S3	2	57.4
V	S3	3	57
V	S3	4	47.5
V	S3	5	51.7
V	S3	6	53.1
VI	S3	1	64
VI	S3	2	54.5
VI	S3	3	68
VI	S3	4	56.2
VI	S3	5	62.6

VI	S3	6	51.8
I	S3e	1	46
I	S3e	2	49.1
I	S3e	3	59.5
I	S3e	4	59.5
I	S3e	5	57.9
I	S3e	6	17.7
II	S3e	1	57.7
II	S3e	2	61.4
II	S3e	3	54.4
II	S3e	4	37.3
II	S3e	5	62.9
II	S3e	6	48.7
III	S3e	1	59.1
III	S3e	2	59.1
III	S3e	3	60
III	S3e	4	54.6
III	S3e	5	58.8
III	S3e	6	58.4
IV	S3e	1	50.8
IV	S3e	2	43.5
IV	S3e	3	53.2
IV	S3e	4	57.6
IV	S3e	5	43
IV	S3e	6	51.7
V	S3e	1	59.4
V	S3e	2	64.4
V	S3e	3	61.4
V	S3e	4	60.1
V	S3e	5	59.9
V	S3e	6	57.3
VI	S3e	1	62.9
VI	S3e	2	67.7
VI	S3e	3	68.8
VI	S3e	4	68.3
VI	S3e	5	66.3
VI	S3e	6	65.6
I	S3w	1	58.7
I	S3w	2	49.7
I	S3w	3	56.2
I	S3w	4	69
I	S3w	5	66.7
I	S3w	6	59.9
II	S3w	1	61.7
II	S3w	2	52.1
II	S3w	3	56.3
II	S3w	4	17.6
II	S3w	5	61.4
II	S3w	6	44.5
III	S3w	1	59.7
III	S3w	2	60.5
III	S3w	3	61.8
III	S3w	4	56.4

III	S3w	5	59.4
III	S3w	6	64.3
IV	S3w	1	56.7
IV	S3w	2	59
IV	S3w	3	45.5
IV	S3w	4	51.4
IV	S3w	5	66
IV	S3w	6	56.2
V	S3w	1	55.7
V	S3w	2	50.2
V	S3w	3	43.9
V	S3w	4	44.6
V	S3w	5	43.9
V	S3w	6	47.2
VI	S3w	1	57.7
VI	S3w	2	59.5
VI	S3w	3	64.5
VI	S3w	4	55.7
VI	S3w	5	72.2
VI	S3w	6	64